

Research Article

Towards a spectrum of dissent: A content analysis of Hawai'i's invasive species media

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Abstract

Invasive species denialism (ISD) has emerged as a concern in invasion science. While some scholars argue ISD is increasing, others contend science denialism is being confused with broader forms of dissent including disagreement and skepticism. Despite attempts to clearly define ISD, most definitions remain subjective and overly reliant on rhetorical markers, creating uncertainty over how to distinguish science denialism from these other, more valuable, forms of dissent. We propose a conceptual framework which utilizes knowledge and porosity as variables to identify science denialism. In doing so, we highlight science denialism's relationship to broader dissent (i.e., skepticism, disagreement, and unfamiliarity). To validate this framework, we conduct a thematic content analysis of media articles discussing the common coquí (*Eleutherodactylus coqui*) in Hawai'i from 1980–2022. We find that while invasive species denialism builds from and amplifies other forms of dissent, it is nevertheless distinguishable within our framework. Moreover, our findings suggest that early and appropriate engagement with dissent can inhibit ISD. Beyond countering ISD, engagement with dissent is important to help mitigate challenges related to distrust of invasion science, issue-framing within public perception, and injustices generated from dismissal. Ultimately, we suggest that the Spectrum of Dissent framework can help scientists, managers, and environmental communication specialists build a healthy dialogue with the public, obtain productive feedback, and facilitate the success of invasive species initiatives.



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Key words: disagreement, *Eleutherodactylus coqui*, science communication, science denialism, skepticism, unfamiliarity

Introduction

Invasive species denialism (ISD), broadly defined as a relentless and unsubstantiated refutation of scientific consensus on invasive species, has emerged as a concern in invasion science - an interdisciplinary field concerned with the study, management, and governance of invasive species (Vaz et al. 2017; Ricciardi and Ryan 2018a). Despite definitional ambiguity (Colautti and MacIsaac 2004a; Shackleton et al. 2022), invasive species are typically defined as species anthropogenically introduced to areas beyond their historical range and whose populations spread, resulting in ecological, economic, or social changes (Lockwood et al. 2013). In 2017, Russell and Blackburn (2017b) raised a concern that ISD is rising in academic and public media. Shortly thereafter, Ricciardi and Ryan (2018a) attempted to illustrate the exponential growth of ISD beyond invasion science's peer review spaces

(e.g. media and opinion articles in academic journals). In response, Boltovskoy et al. (2018) countered such claims by noting the percentage of legitimate ISD is minute and has not increased since 1990. Regardless, the existence of ISD presents a serious concern as studies within the arena of climate change suggest that even small amounts of science denialism can hamper policy outcomes, decrease public trust of experts, and reduce public perception of scientific consensus (Biddle and Leuschner 2015; Koehler 2016; Ranney and Clark 2016; Stuart et al. 2022).

Despite ongoing debate over the magnitude of the problem, addressing ISD requires a systematic way of identifying it. Russell and Blackburn's (2017b) article about ISD prompted heated debate in invasion science regarding what constitutes ISD (Briggs 2017; Crowley et al. 2017b; Davis and Chew 2017; Tassin et al. 2017). Indeed, some scholars have suggested that disagreement and skepticism in invasion science are being misinterpreted as science denialism (Crowley et al. 2017b; Frank 2021). Others, meanwhile, contend that these disputes may be the result of how different individuals frame ISD (Stratton et al. 2022). Such critiques, expanded on in the subsequent section, are generally grounded in one of two arguments: 1) ISD definitions are inadequate (Crowley et al. 2017b; Frank 2021), and 2) the methods utilized to identify ISD are insufficient (Munro et al. 2019).

Together, these exchanges outline a landscape of uncertainty around how to identify ISD, and what distinguishes it from broader dissent, defined here as objections to scientific consensus grounded in skepticism, unfamiliarity, or disagreement (Frank 2021). Building on this observation, we propose a framework to distinguish science denialism from broader dissent. This is critical because where science denialism may be detrimental in its effects, broader dissent can be incredibly useful for invasion science. Indeed, Stratton et al. (2022) and Frank (2021) both suggest that more nuanced responses are needed to address ISD, strengthen invasion science, and advance management outcomes.

In this article, we engage with the issue of ISD, with a goal to 1) more clearly distinguish it from and 2) outline its relationship to broader dissent on invasive species. Without a clear conceptual mapping of dissent, invasion science scholars/practitioners risk confusing science denialism with other, more valuable, forms of dissent. This can be problematic given power structures in science that have historically privileged certain forms of knowledge (e.g., Western) while devaluing others (e.g., Indigenous) (Harding 1991; Mignolo 2005; Elk 2016). Attention to power is critical in invasion science (Gonzalez Cruz and Johnson 2022; Shackleton et al. 2023), a field which while making strides to improve, continues to struggle with gender imbalances (Campbell and Simberloff 2022), skewed racial and geographic representation (Kuebbing et al. 2022), and limited engagement with and consideration of alternative worldviews (Wehi et al. 2023).

While a handful of studies have examined ISD (Russell and Blackburn 2017b; Boltovskoy et al. 2018; Ricciardi and Ryan 2018a; Munro et al. 2019; Frank 2021; Stratton et al. 2022), and noted that ISD primarily occurs beyond peer review (Russell and Blackburn 2017b; Ricciardi and Ryan 2018a), few have focused exclusively on its manifestation in the media. We address this gap via an examination of invasive species media in Hawai'i, focusing on *Eleutherodactylus coqui* - hereafter coquí. Hawai'i represents an exemplary microcosm to study invasive species dynamics due to its sociocultural dynamics, immense biodiversity and growing experience with invasive species management (Pejchar et al. 2020). The coquí is a tree frog endemic to Puerto Rico, where it is heralded as a longstanding cultural icon

(Joglar 2005). Inadvertently arriving in the 1980s, the coquí became established in Hawai‘i. The coquí’s spread throughout the Hawaiian archipelago generated substantial contention between the public, policymakers, and scientists both in Puerto Rico and Hawai‘i about 1) the extent to which coquí posed a problem/threat to Hawaiian socio-ecological systems, 2) how it should be managed, and 3) whether the management approaches ultimately employed were science-based and/or ethical (Beard and Pitt 2012). We leverage the tension around coquí to conduct a thematic content analysis of media discourse. Our objectives are threefold: 1) present a framework that helps distinguish between ISD and broader dissent; 2) validate our framework; 3) identify obstacles to effective invasion science communication. The proposed framework can inform broader environmental communication discourse on adjacent subjects with growing science denialism (i.e. extinction, and climate change).

In the next section, we provide a brief sketch of the current limitations to identifying ISD, outline a theoretical overview of dissent, highlight the importance of discernment, and situate our discussion within literature on environmental communication. In the third section, we outline our methods. Finally, we share our results within a larger discussion on the precautionary principle, message framing, and stakeholder dismissals. We conclude with a note to guide invasion science’s future engagement with ISD, and articulate avenues for prospective research.

ISD and current limitations to identifying it

Scholars within invasion science have grouped several arguments under the umbrellas of contrarianism (Simberloff 2011; Richardson and Ricciardi 2013; Simberloff and Vitule 2014; Kuebbing and Nuñez 2018), and/or, more recently, ISD (Russell and Blackburn 2017b; Ricciardi and Ryan 2018a). For example, Davis et al. (2011) argue that a species’ origin should not play a significant role in determining what is/not an invasive species, while Pearce (2015) and Briggs (2017) contend there is little evidence connecting invasive species to major contemporary extinctions. Sagoff (2018) claims that definitions within the field contain tautologies (e.g. biodiversity) and normative dimensions (e.g. harm), while Guerin (2019) asserts that a bias towards the negative impacts of invasive species presents problems for broader generalizations within the field. Others go further, arguing that invasion science is biased, pseudoscientific, and/or an unnecessary subdiscipline within ecology (Davis and Thompson 2002; Theodoropoulos 2003; Valéry et al. 2013). Invasion science scholars have actively responded to criticisms of and within the field, particularly those seen as contrarian or ISD (Simberloff and Vitule 2014; Ricciardi and Ryan 2018b). We allude to these arguments not as an endorsement, nor as a comprehensive review, but rather to illustrate the breadth of arguments currently included under ISD.

While academic attention to ISD is a relatively recent phenomenon (Russell and Blackburn 2017b), science denialism in and of itself is not novel. Science denialism has been observed in the realms of climate change (Rahmstorf 2004; Antilla 2005; Capstick and Pidgeon 2014; Björnberg et al. 2017), extinction (Lees et al. 2020), tobacco smoking (Oreskes and Conway 2011; Proctor 2012), HIV/AIDS (Nattrass 2007, 2012), and, more recently, COVID-19 (Malinvernini and Brigagão 2020). This scholarship broadly recognizes science denialism as an extreme form of dissent along a continuum (Dunlap 2013; Corry and Jørgensen 2015; Kumar et al.

2016; Haltinner and Sarathchandra 2021). Researchers have explicitly recognized this continuum in invasion science, underscoring that concepts like skepticism and disagreement should be considered distinct from science denialism (Crowley et al. 2017b; Russell and Blackburn 2017a; Ricciardi and Ryan 2018a; Frank 2021). Despite this recognition, systematic identification of ISD has been hampered by two interrelated challenges: 1) variable definitions of science denialism (Crowley et al. 2017b; Frank 2021; Stratton et al. 2022); and 2) a methodological overreliance on rhetorical markers as confirmation of science denialism (Munro et al. 2019).

With regard to the first challenge, existing literature underscores that the way we define science denialism is important because it carries implications for how we study and come to recognize it. In research with participants from the Great Lakes region, for example, Stratton et al. (2022) find that multiple framings of ISD exist, suggesting that ISD is not universally defined. Indeed, invasion science has utilized multiple, often competing, definitions to engage with science denialism. For example, Russell and Blackburn (2017b) suggest science denialism is “where evidence is disregarded, or motivations are disingenuous” (p. 4) and the “rejection of undisputed scientific facts (p. 4). In their study of science denialism within scholarly journals and the mainstream media, Ricciardi and Ryan (2018a) define ISD as the use of “rhetorical arguments to disregard, misrepresent or reject evidence in an attempt to cast doubt on the scientific consensus that species introductions pose significant risks” and the act of “ignoring or denying scientific facts and making claims that have already been refuted in the peer-reviewed literature” (Ricciardi and Ryan 2018a). Although within seminal texts on ISD, such definitions have been critiqued for assigning motivation (i.e. casting doubt) as a fundamental characteristic of ISD (Frank 2021). This critique arises because motivation is notoriously difficult to ascertain (Frank 2021). Speculation of motivation may be more useful for addressing science denialism, but less so for identifying it. In an attempt to sidestep issues of motivation, Frank defines ISD as “normatively inappropriate dissent” which both violates epistemic norms (e.g. straw-man arguments) and is anticipated to cause harm (e.g. delays necessary management) (2021). This definition, while generative remains problematic because expected harm is similarly difficult to assess and may not be comprehensible until after the harm is done, a shortcoming Frank (2021) recognizes. The definitions presented herein each contain strengths and weaknesses. Thus, we contend that this definitional problem remains.

With regard to the second challenge, Hoofnagle and Hoofnagle (2007) and Diethelm and McKee (2009), from which Ricciardi and Ryan (2018a) and Frank (2021) draw in their definitions, suggest that denialists utilize common rhetorical strategies in lieu of facts to build arguments against scientific consensus and heaps of evidence (Hoofnagle and Hoofnagle 2007). These rhetorical markers were later consolidated into a comprehensive framework entitled FLICC: fake experts, logical fallacies, impossible expectations (e.g. seeking 100% certainty), cherry-picking, and conspiracy theories (Hoofnagle and Hoofnagle 2007; Diethelm and McKee 2009; Cook 2017). While we acknowledge and affirm the value of rhetorical markers, we simultaneously point to the foundational premise of this argument which is that science denialists commonly use such rhetorical techniques, not that such rhetorical techniques are unique to science denialists. This distinction clouds the utility of such rhetorical tactics for distinguishing science denialism from broader forms of dissent, which might also utilize such strategies. Thus, we assert that

current methods which outline FLICC markers as pivotal to the identification of ISD are insufficient for distinguishing it from broader dissent. Munro et al. (2019) similarly suggest that current methods are insufficient, though their claims arise from efforts to replicate Ricciardi and Ryan's (2018a) study of ISD. Overall, these issues make it difficult to develop healthy dialogue regarding ISD and underscore that a more systematic approach to identifying ISD is needed (Guiașu and Tindale 2018; Frank et al. 2019).

In light of these definitional and methodological problems, we suggest invasion science should be more intentional with its conceptualization of science denialism and its relationship to other forms of dissent. While we identify and build from existing critiques concerning ISD, such challenges are not unique to invasion science. Indeed, climate change denialism literature has seen similar pushes to refine its conceptual language to move away from dichotomies (e.g. denier/believer) and/or imprecisions (i.e. climate skeptic) (O'Neill and Boykoff 2010; Björnberg et al. 2017), and better differentiate between doubt over science (epistemic and fact-based) as opposed to doubt over policy and solutions (value-based) (Capstick and Pidgeon 2014). Ultimately, the ability to systematically identify ISD in invasion science is critical to build a more productive dialogue in a field characterized by areas of both high consensus and polarization (Shackleton et al. 2022).

Theorizing dissent within invasion science

Building on invasion science's acknowledgement of ISD as part of a continuum, we offer a framework which situates science denialism along a spectrum of broader dissent (Fig. 1). In suggesting a move beyond dichotomous vocabularies of non/denialism in climate change science, Corry and Jorgensen highlight the common thread linking such labels in the literature is information and the underlying claims of validity (2015). As such, we conceptualize dissent as an embodiment of four distinct relationships to information: disagreement, skepticism, unfamiliarity, and denialism.

To limit definitional ambiguity and address the limitations outlined above, we draw from Ricciardi and Ryan (2018b) and Ferkany (2015) to suggest science denialism be defined as— an iterative pattern (1) of espousing unsubstantiated knowledge claims (2), refuting scientific evidence (3), and eluding opportunities to learn or adapt with new/updated information. Together, these characteristics display evidence of a low knowledge base and low porosity to new information, without overly relying on FLICC rhetorical markers and/or motivation. When examining a particular interaction utilizing the spectrum of dissent, an individual or community's position is characterized by their knowledge base (i.e., demonstrated knowledge/understanding about the issue) and their porosity to new information (i.e., indicated probability that additional information would alter one's perspective) (Fig. 1). An individual's knowledge base is determined by the in/accuracy of information presented in or underlying their remarks. Porosity, on the other hand, is determined by expressions of open/closed mindedness - characteristics which Ferkany (2015) utilize to distinguish between naive denial and a more dogmatic denial. Open-mindedness is characterized by things like generative dialogue, regard for other's viewpoints, good-faith questions/curiosity, whereas close-mindedness is characterized by the opposite (e.g., entrenched stance, firm dialogue, disregard).

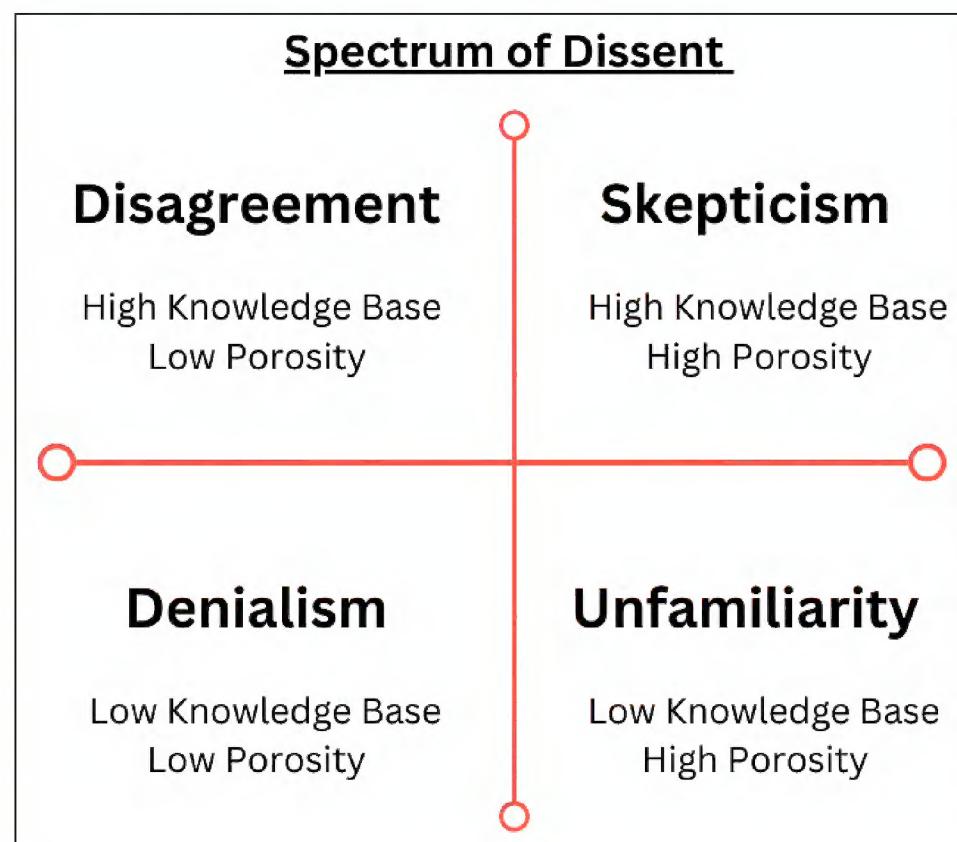


Figure 1. Spectrum of Dissent. The spectrum demonstrates the relationship between disagreement, skepticism, unfamiliarity, and denialism, which are all types of dissent. The x-axis represents porosity to new information (likelihood that additional information would change one's perspective). The y-axis is represents knowledge base (extent an individual or community is knowledgeable about a subject).

Based on this framework, we expect someone who dissents out of disagreement may exhibit knowledge of the subject matter but fundamentally diverge in opinion or interpretation. Similarly, an individual with unfamiliarity, in this framework, may naively deny scientific details but maintain an openness to shifting their position with new information (Ferkany 2015; Mason 2020). Such dissent is distinct from science denialism, which is grounded in denial that actively eludes correction (Ferkany 2015). Invasion science researchers generally recognize science denialism is also distinct from skepticism, an organic component of the scientific process which may question scientific conclusions with substantiated claims, but is ultimately receptive to dialogue and updated information (Russell and Blackburn 2017b; Ricciardi and Ryan 2018a; Frank 2021; Jylhä et al. 2023).

In basing determinations of knowledge base and porosity on displays of behavior, we attempt to remove the (sometimes speculative) consideration of cognitive beliefs and/or motivations. Thus, while some science denialists have deliberately lied, hiding their true (high) knowledge base to gain attention, financial incentives, or other benefits (Diethelm and McKee 2009; Björnberg et al. 2017), their exhibited behaviors were of a low knowledge base and low porosity. The exhibited behaviors are those with which scientists and the public must contend when identifying science denialism, and thus the focus of our framework. Moreover, the spectrum of dissent is intended for use on a case-by-case assessment, and in no way indicates that an individual acting as a science denialist in one instance will do so in every instance. Thinking about ISD in terms of a spectrum of dissent may make it easier for scientists and policymakers to pinpoint the form of dissent present/represented and thereby facilitate a healthier or more constructive dialogue (Hoffman 2011).

Dissent and power

A conceptual framework that systematically distinguishes between denialism and other forms of dissent is critical because dissent is often recognized as contributing to revo-

lutionary advances in science (Kuhn 2012). Skepticism and disagreement have already proven valuable for invasion science; prior waves of criticism, for example, have demonstrably reduced context bias (Warren II et al. 2017). Longstanding debates around topics like the enemy release hypothesis (Colautti et al. 2004) or the passenger-driver model (MacDougall and Turkington 2005), and recurring critiques about the field's language (i.e. militaristic, colonial, xenophobic) and normative/value-laden dimensions continue to challenge the field (Subramaniam 2001; Colautti and MacIsaac 2004b; Larson 2008; Essl et al. 2017; Reo et al. 2017; Janovsky and Larson 2019). Moreover, in a survey of the field, Shackleton et al. (2022) identify several moderate to highly polarizing topics within invasion science, including questions of whether the field is objective, whether invasive species benefits are understated; if non-native species should be included or excluded in biodiversity counts, what constitutes the definition of invasive species, and what the feasibility of plant eradication is, to name a few.

Yet, due to the field's complexity, its value-laden aspects and the polarization evident in some areas of the field, there is concern that some scholars have leveraged charges of ISD to silence scientific and ethical debates (Crowley et al. 2017b; Frank 2021; Stratton et al. 2022). Recently, Davis (2020) likened some of invasion sciences' responses to dissent as gang science, a practice of scientists banding together to argue against challenged ideas in a way that can be read as intimidation or bullying. Such tense dynamics are especially troubling because although ISD has the potential to greatly impede invasive species scholarship and management, spurious allegations run the risk of dismissing valid concerns, undermining diverse communities and their knowledge, and/or furthering systemic injustices (Frank 2021).

Shackleton et al. (2023) urge attention to dissent and encourage conservationists to "be wary of how consensus and the absence of conflict might sometimes be the product of power relations" (p. 10). Such tensions demand reflection about how consensus forms, especially amidst public dissent. This is particularly important in the context of Hawai'i and Puerto Rico - two archipelagos colonized by the United States. Some Indigenous communities, in Hawai'i and beyond, for example, have exhibited different language and frameworks for thinking about "invasive species", which are at times at odds with "conventional" invasion science (Bach and Larson 2017; Reo and Ogden 2018; Wehi et al. 2023). If "science denialism is the rejection of undisputed scientific facts" as Russell and Blackburn (2017b) contend, the question remains: undisputed by who? (Crowley et al. 2017b). Such definitional bounds may inadvertently devalue stakeholders' voices and superimpose dominant perspectives. We contend that such epistemic injustices (i.e., negating credible knowers) can reproduce the field's current demographic disparities (McConkey 2004; Campbell and Simberloff 2022; Davinack 2022; Kuebbing et al. 2022). For example, a recent study by Kuebbing et al. (2022) suggests that while the current make-up of the editorial board for the journal of "Biological Invasions" is more diverse than it historically has been, it remains largely white (85%), English speaking (70%), male (60%), and US-based (nearly 50%).

This begs the question: How can invasion science foster productive dissent, which helps create a more just discipline and practice, without heightening claims of ISD? We suggest the ability to accurately and analytically identify ISD could enable less fearful or dismissive engagement with wider dissent, which may simultaneously provide opportunities to build trust and facilitate stakeholder engagement around emergent public concerns. Ultimately, such an effort can improve science-society relations while also opening invasion science and management to more diverse approaches.

Science denialism in media

An important area for invasive species communication is media, from contemporary social media (e.g. YouTube, Facebook, etc.) to print media (Davis et al. 2018). Here, we focus on print media. Journalism practice norms play a pivotal role in the development of different forms of dissent. For example, media, in an effort to achieve neutral and balanced reporting, may create an echo chamber wherein denialist thought is disproportionately amplified and promoted, producing an illusion of scientific debate (Elsasser and Dunlap 2013). The allure of sensational or attention-grabbing stories such as conflict tend to draw greater attention to science denialism in media (Brüggemann and Engesser 2017), potentially boosting the reach of misinformation.

Given its potential role in amplifying denialism, and the growing interest in ISD, more empirical research on dissent in invasive species media is needed (Russell and Blackburn 2017b; Ricciardi and Ryan 2018a). Invasive species are increasingly covered as a newsworthy topic and thus open to public debate in news stories, editorials, and public letters. Indeed, if invasive species stakeholder engagement is limited and participation does not actively inform decision-making as research suggests (Shackleton et al. 2019), media may currently provide the most approachable (and perhaps democratically effective) means of voicing broader dissent and influencing invasive species outcomes. Furthermore, recent research demonstrates how media's portrayal of invasive species can positively or negatively influence public perception of the species (Geraldi et al. 2019; Ballari and Barrios-García 2022), its management (Leppanen et al. 2019), and/or related policy (Miller et al. 2018).

In a study comparing scientific and media coverage of ecological effects, for instance, Geraldi et al. (2019) found invasive species media cycles to be relatively brief, lasting one to two years. They suggest this is likely due to a temporal reduction in "newsworthiness" and invasive species impacts failing to live up to the media's exaggeration of risks. It is worth noting that such news cycles vary by species, with many species receiving little to no coverage at all (Ballari and Barrios-García 2022). Leppanen et al. (2019) further outline how media obscure or omit uncertainty over, and scientific debate of, invasive species management, including concerns over efficacy and non-target species effects. These studies illustrate a growing interest in invasive species media and provide key findings to guide science communication. Invasive species media thus provides an important, but understudied, empirical avenue for studying ISD.

Hawai‘i, the coquí, and dissent

Hawai‘i has been embroiled in a public debate over the coquí since its introduction. The coquí quickly spread to all four principle islands (Hawai‘i, Maui, O‘ahu, and Kaua‘i), though it is presently contained to Hawai‘i and Maui (Beard et al. 2017). A nocturnal terrestrial frog which undergoes direct development (i.e. no tadpole stage), the coquí is most prominently recognized by its two-tone mating call (Beard et al. 2017). Indeed, its iconic nocturnal call, combined with its status as a charismatic invasive species, has helped generate a heightened public, and thus media response in Hawai‘i (Kraus 2009; Jarić et al. 2020b). In contrast, the coquí has a long-standing reverence in Puerto Rico, symbolically represented from

pre-colonial Borikén petroglyphs to present day consumer products in Puerto Rico and the wider diaspora, including jewelry, toys, art, music, etc. (Joglar 2005). As a species of great cultural significance to people in one US colony (Puerto Rico), and a subject of eradication in a different US colony (Hawai‘i), it is apropos to discussions on power and knowledge.

Methods

Content analysis is a media analysis tool within communication studies that allows researchers to systematically comb through large textual datasets while documenting patterns in the process (Krippendorff 1980). With the capacity to combine qualitative and quantitative techniques, content analysis can yield insights that advance conservation goals (e.g. documenting subjects of attention, effects of communication, dominant voices, etc.) (Krippendorff 1989; Wolch et al. 1997; Muter et al. 2009; Houston et al. 2010; Renz et al. 2018). Following methodologies for media analyses of invasive species (Geraldi et al. 2019; Leppanen et al. 2019; Ballari and Barrios-García 2022; Tateosian et al. 2023) and other conservation contexts (Jacobson et al. 2012; Muter et al. 2012; Unger and Hickman 2020), we constructed a content analysis protocol to 1) guide inclusion/exclusion of media articles, 2) code for the presence/absence of dissent and other descriptive details, and 3) inductively draw out significant dissent themes. While briefly summarized here, the full protocol is included in supplementary materials (Suppl. material 1).

This study built its corpus using the Star Advertiser Archive, which holds a fully searchable subsection of Hawai‘i’s newspapers dating back to 1840, including the Hawaii Tribune-Herald, Honolulu Advertiser, Honolulu Star-Bulletin, West Hawaii Today, The Polynesian, The Daily Bulletin, The Hawaiian Star, The Evening Bulletin, and the Garden Isle. A search for articles on the coquí using its common name “coquí” was conducted in Spring of 2023, yielding 2,974 pages. Documents collected in the corpus were manually screened to ensure they met the following inclusion criteria: 1) Focus on coquí; 2) discusses species in the context of Hawai‘i; 3) relevance (e.g., excludes advertisements); and 4) does not concern species in captivity. Documents that failed the inclusion criteria and duplicates were removed, resulting in a total of 445 documents for analysis. See Suppl. material 2 for a full list of included media.

We coded data across four blocks of content categories: metadata, coquí natural history, dissent, and descriptors and key events. Block one (metadata) included information such as date of publication, title, author(s) name, author(s) affiliation, forum of publication, publication type (e.g. news article, opinion piece, etc.), article valence, and language. Following Golebie and colleagues, article valence (e.g. positive, neutral, negative) was dictated based on the tone of how the coquí was discussed (2022). For example, “negative” framing was assigned to articles which emphasized the need for eradication due to the coquí’s “nuisance”, “noisy”, or “shrill mating call”. Terminological language (i.e. pest, non-native, invasive, etc.) utilized to discuss the coquí was also coded. Block two consisted of details related to the coquí’s impact and risk, coded as present or absent. We differentiated risk from impact (present or past oriented) by its future orientation. Block three addressed dissent. To distinguish dissenting articles from non-dissenting articles, dissent, as a whole, was characterized by the presence of oppositional statements (i.e.

disagreement, disbelief, and/or skepticism). Block four focused on descriptors and key events to assist with a timeline reconstruction of events. Following Alexander and Quinn (2012), we documented words describing the coquí within media articles to qualitatively explore thematic word clusters. Finally, media interest in the common coquí was quantified by the number of publications per year. Additionally, as part of our literature review, we conducted a Scopus and Web of Science search of coquí research in Hawai‘i. This served to contextualize claims made in the media and provide a baseline comparison between scientific and media attention (Geraldi et al. 2019).

The first author was involved in full content analysis and protocol development; additional authors coded a subset of the articles. To assess interrater reliability, a portion of the corpus was selected at random ($n=50$) and given to each author for independent coding. We used Cohen's Kappa and Gwet's coefficient to measure intercoder reliability (Cohen 1960; Cohen 1968). Strong agreement is indicated by kappa values above 0.75 (Banerjee et al. 1999). Occasionally, a low kappa will result despite high percentage agreement due to the effects of variable prevalence on the determination of chance, a factor known as the paradox of kappa (Gwet 2008). In other words, a high imbalance between the presence/absence of variables can lead to a greatly lowered kappa value even with few disagreements. To address this fault, we also calculated Gwet's AC_1 coefficient (Gwet 2002). Kappa values and Gwet's AC_1 coefficient were calculated for each variable using ReCal2 (Freelon 2010) and R Statistical Software version 4.3.1 (v. 4.3.1; R Core Team 2022), as well as the irrCAC R package (Gwet 2019), respectively. Per content analysis best practices (Lacy et al. 2015), variables that did not meet the standard of intercoder reliability were revisited, discussed until coder consensus was reached, and adapted in the codebook to reflect outcomes of discussion. Upon reaching consensus and coder re-training, an additional subset of articles were coded ($n=25$) and tested for intercoder reliability, yielding high agreement (Table 1). Any variables where reliability was not achieved were dropped (see Suppl. material 1 for more information).

While content analysis allowed for a reliable identification of dissent, thematic analysis provides a methodology to dig deeper into these codes and parse out patterns that would yield insights into science denialism and broader invasive species dissent. Thematic analysis is an iterative qualitative method best utilized to identify patterns or themes within a data set (Boyatzis 1998). Thus, we immersed ourselves in the dissent data, generating descriptive codes as they emerged, which were then further grouped into themes and sub-themes (Javadi and Zarea 2016).

Table 1. Intercoder reliability results, including percentage agreement, Cohen's Kappa, and Gwet's Coefficient for each variable, as an example.

Intercoder reliability results ($n=25$)				
Variable	Example	% Agreement	Cohen's Kappa	Gwet's coefficient
Publication Type	Opinion Piece	96	0.935	0.942
Valence	Negative	100	1.000	1.000
IS Language	Pest	92	0.880	0.904
Impact	“We can no longer sleep with windows open due to noise”	92	0.818	0.858
Risk	“I imagine property values will drop”	96	0.919	0.921
Dissent	“It was first stated that they were a threat to our native birds by competing for insect food. A convincing argument has not been made for this”	88	0.603	0.830

Results and discussion

Coquí coverage

Nearly 47.6% of the media were news articles ($n=212$), while another 40.2% were opinion pieces ($n=179$) and the remaining 12.1% were feature columns ($n=54$). The quantity of opinion pieces, in comparison with news media, demonstrates a substantial public interest in coquí issues and highlights the media as an attractive venue for invasive species discussion. This reflects the agenda-setting hypothesis which states that levels of media coverage coincide with public importance of those topics (McCombs and Shaw 1972).

As a contributor to public perception and behavior (de Vreese 2005), valence, or a message's tone, is key to understanding dissent. Akin to Ballari and Barrios-García's (2022) findings on valence in invasive species media, coquí media valence skewed negative (82%), with neutral (11.4%) and positive (6.5%) valence minimally represented. This negative skew is largely due to an emphasis on the coquí as a noise nuisance, and, to a lesser extent, its potential impact on native species. This is reflected in the distribution of descriptor words. Of 268 descriptor words, 45% described the coquí's mating call in terms like "annoying", "deafening", "clamorous", or in metaphoric descriptors – like a "jet engine", "chainsaw", "jackhammer", "alarm clock", and more. While communication of negative aspects is an integral part of invasive species communication, an overly negative valence can also foster feelings of helplessness in some individuals with implications for management outcomes (Golebie et al. 2022).

Coquí impact and risk narratives, emerging in 1999, included ecological, social, and economic effects, though scientific research on these concerns occurred later (Fig. 2). Approximately 61% of media articles ($n=271$) brought up impacts, while about 44% ($n=198$) invoked risks attributed directly to, or indirectly to, the coquí. Recall that risk is a potential or future oriented impact and suggests greater uncertainty. Within the 198 pieces of media, 323 individual risk references were made, of which nearly half were ecologically focused ($n=159$). Almost eight percent of media pieces ($n=35$) alluded to the risk of invasional meltdown, which stipulates that invasive species facilitate subsequent species invasions (Simberloff and Von Holle 1999; Braga et al. 2018). Economic risks were mentioned in 25.7% of articles ($n=59$). Of the 271 articles which brought up impacts, 352 individual impact references were made. Approximately 68% ($n=242$) of these centered social impacts via the coquí's mating call (e.g. sleep disturbance, annoyance, etc.), while economic impacts and ecological impacts were equally referenced about 16% of the time ($n=55$). The dominant focus on the coquí's social impact is critical to note because iterative exposure to such messages can reinforce or cultivate how people think about a subject matter (Gerbner 1998).

Maximum annual media coverage occurred in 2005 ($n=67$), aligning with Geraldi et al.'s (2019) observation that this generally occurs six years post initial media coverage (Fig. 3). Overall, the bulk of media was published between 2001 and 2010 ($n=354$), whereas more than half of scientific publications on coquí in Hawai'i were published after 2010 ($n=26$), suggesting media interest decreased as scientific publications increased (Fig. 3). Two factors likely contributed to these observations. First, an official narrative concerning coquí impacts/risks emerged in 1999, despite delays in the scientific study of such impacts/risks (Fig. 2). This gap in time between communicated risks/impacts and studied risks/impacts is due, in part, to the slow and

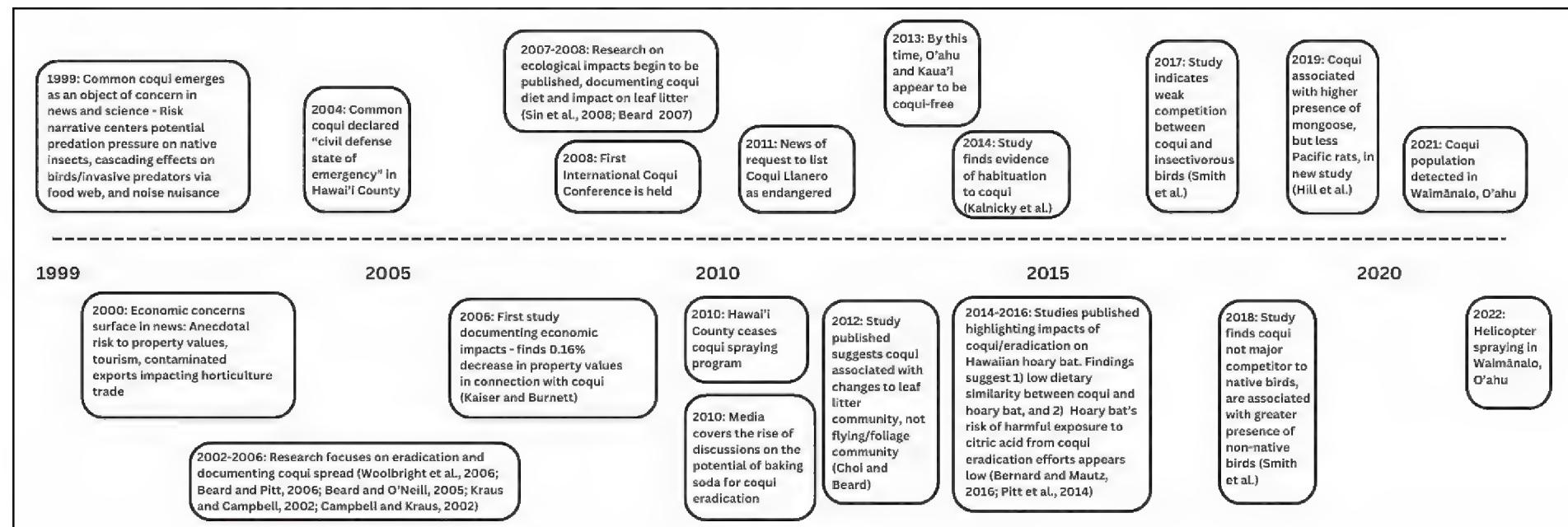


Figure 2. Timeline of coquí impact and risk. Timeline illustrating when major concerns surfaced in comparison to when they were studied.

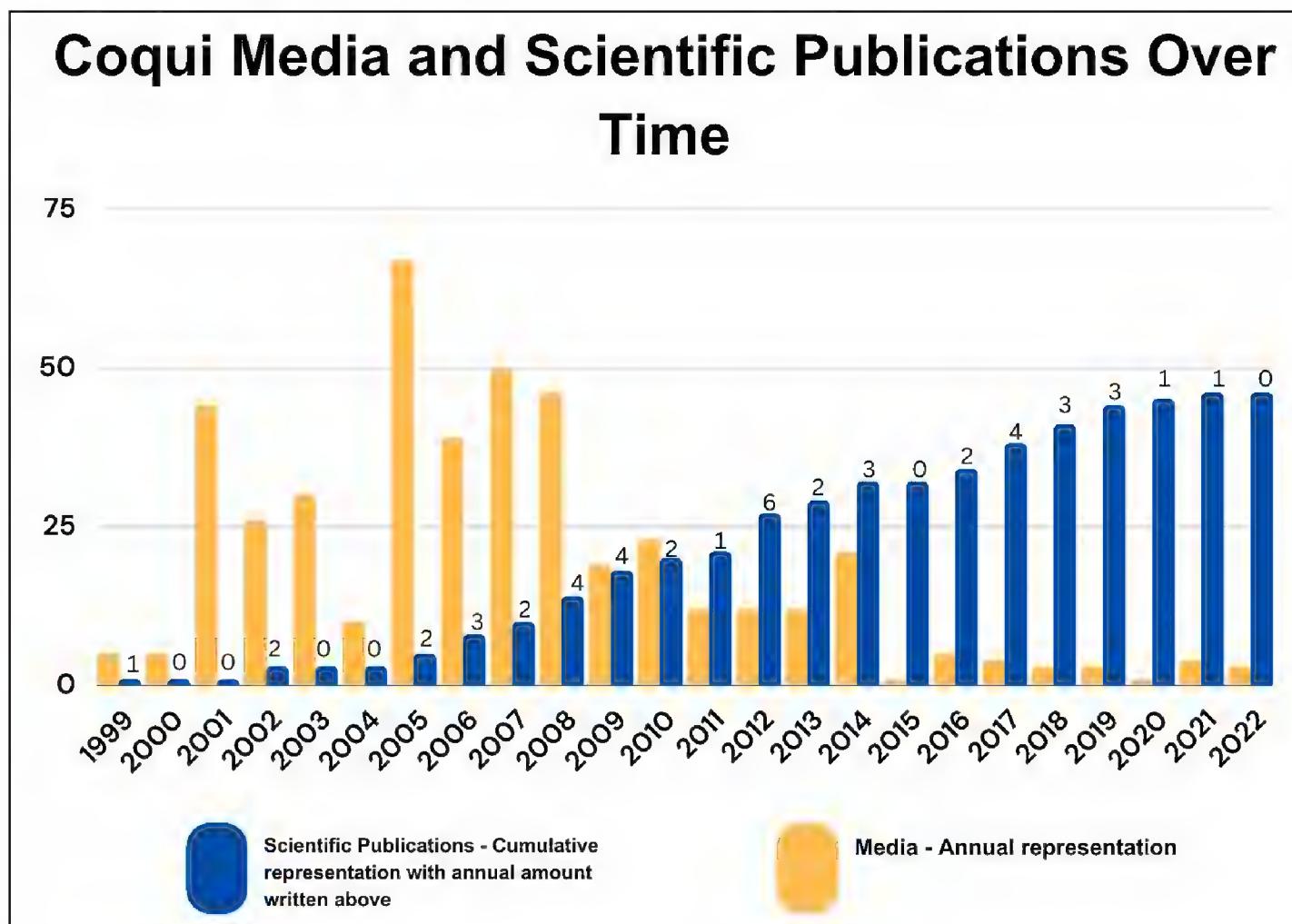


Figure 3. Coquí media and scientific publications over time. To accommodate the scalar difference, annual quantities of coquí media are represented in orange while scientific publications, in blue, are a cumulative representation with annual quantities highlighted above each bar.

often extensive nature of invasion species data collection and the common lag in invasive species impact detectability (Simberloff 2010). While acknowledging the complexities of invasion science, we suggest this gap represents a “fragile moment” for invasive species communication and management, wherein dissent is more likely to arise. This observation is bolstered by studies in parakeet management which similarly suggests that time is an important factor in the way management policies are viewed and received by the public (Crowley et al. 2019). Second, over time, group dynamics solidify and peer pressure to conform to broader social consensus heightens such that voicing opposing sentiments/thoughts is increasingly frowned upon. Indeed, research shows that social consensus is critical in shaping belief and behavioral non/acceptance on polarized issues (Goldberg et al. 2020). For example, in the same month as the First International Coquí Conference, someone wrote:

“After being all but hung in effigy for objecting to the inhumane genocide of the coquí in my neighborhood, I had promised myself that protecting my pets from possible retaliation was more important than voicing my views. However, thanks to the recent letters from [Redacted Name] of Hilo and [Redacted Name] of Honokaa, I have, again, found my backbone. Several points come to mind: Research has shown that the coquis do, indeed, eat the nasties – cockroaches, ants, centipede larvae and even possibly those Chinese rose beetles mentioned by [Redacted Name] (when available from the scorched earth, our native birds seem fat and healthy in spite of the suggested competition)....” - Individual-A (2008)

Thus, while delays in science represent an organic, and perhaps inevitable component of invasion science, they nonetheless hold implications for dissent formation and proliferation - a point we return to in the section entitled “Skepticism as dissent”.

Documenting dissent

Documenting dissent and its focus is another critical step to understanding wider debates around the coquí and whether they represent science denialism. Of the 445 media articles studied, only nineteen percent (85/445) exhibited dissent. This could be attributed to the dominant discourse that emerged after introduction, which characterized the frog as an invasive species with negative impact. While relatively more uncommon, dissent nevertheless emerged immediately - only two weeks after the first media coverage of invasive coquí. Terminological ambiguity (i.e. invasive species, pest, introduced species, among others), a source of debate in the literature (Latombe et al. 2019), did not play a prominent role in dissent formation in the public realm.

Instead, our thematic content analysis revealed that dissent largely concentrated on impact and eradication. These findings support previous observations of invasive species conflict (Crowley et al. 2017a). More specifically, we found that eradication dissent centered on specific practices, the logic or evidence underlying eradication decisions, and whether the coquí should be prioritized for eradication. Impact dissent was attributed to the timing of the underlying science and the experience of invasive species impacts. Yet, impact dissent and eradication dissent are tightly interwoven. This linkage between impact dissent and eradication dissent may be an example of uncertainty transfer, wherein uncertainty in one area influences perceptions of uncertainty in another (Spence et al. 2012).

Skepticism as dissent (high knowledge, high porosity)

To an extent, skepticism emerges naturally in invasion science. Although all invasive species are introduced, not all introduced species become invasive, and, in fact, many are innocuous (Ricciardi and Ryan 2018b). An invasive species that is established and spreading, however, generates concern over potential negative impacts, even if currently unknown (Lockwood et al. 2013). Despite advances, impact forecasting overall remains a challenge for the field (Ricciardi et al. 2021). To prevent the most serious socio-ecological effects from occurring, invasion scientists have adopted a precautionary approach (Shackelford et al. 2013). The precautionary principle for invasion scientists flips the burden of proof such that action is not delayed as a result of insufficient information (Gonzalez-Laxe 2005).

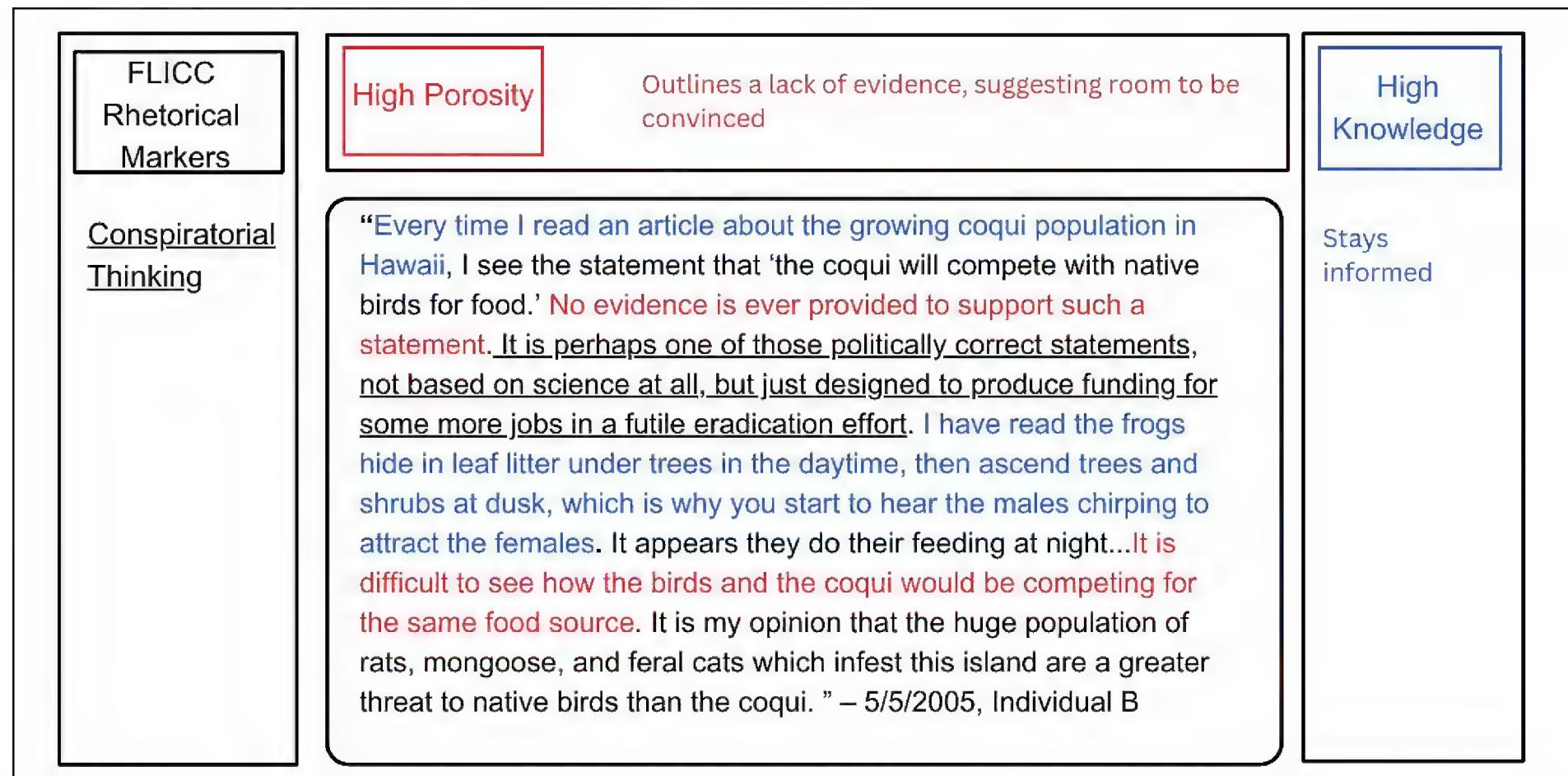


Figure 4. Skepticism. Close reading sample of Individual-B (2005), highlighting FLICC markers as well as the porosity and knowledge characteristics which identify it as skepticism.

Invasion scientists often cite two major challenges to acquiring relevant data quickly. First, species impacts may remain undetectable for decades or centuries (Simberloff 2010), and waiting until impacts manifest may result in catastrophic and/or irreversible ecosystem changes. Second, the species and/or ecosystem in question may be data-poor (i.e. species lacks invasion history or ecosystem is under-studied such that impact is difficult to discern) (Pyšek et al. 2020). As a result, the rapid dispersal of newly introduced species often prompts eradication (Simberloff and Vitule 2014).

This approach presents a temporal conundrum in the initial stages of the invasion process, wherein the public is invited to engage in eradication practices based on scientific speculation and experience, rather than concrete evidence. For the public, tangible impacts are often a critical contributor to their perception of invasive species (Simberloff et al. 2013). This disciplinary quandary is best characterized by dissenters’ calls for “more evidence” or claims of little to “no evidence”, as Individual-B (2005) expresses (Fig. 4). Such opposition to the precautionary approach and its underlying justification have been previously linked to invasive species conflict (Crowley et al. 2019).

Individual-B (2005) highlights their attention to coquí news, alluding to high knowledge. Their focus on and desire to see evidence suggests high porosity, despite their conspiratorial suggestion. As conspiracies are a FLICC rhetorical marker for science denialism (Hoofnagle and Hoofnagle 2007), we highlight Individual-B’s remark to illustrate FLICC’s insufficiency for distinguishing between science denialism and broader dissent under conditions of high uncertainty.

Indeed, coquí dissenters often articulated skepticism of negative risks because they had yet to visibly manifest and science was lacking. The precautionary approach, while critically important in many instances, can nevertheless foster distrust of scientific claims. This dynamic produces a tricky terrain for invasion scientists to navigate as they attempt to reinforce concern. Indeed, upon studies in

2014, scientists learned that coquí did not appear to be in competition with native birds (Smith et al. 2018). As Smith and colleagues suggest, this finding “should not be surprising, because coquís in Hawaii mostly forage in the leaf litter, whereas most extant Hawaiian birds forage on insects in the canopy and understory” (2018). Other studies did find evidence for negative impact, however. Smith and colleagues found that coquí presence increase the abundance of non-native birds (Smith et al. 2018); Choi and Beard (2012) learned that coquí alter invertebrate communities; Hill and colleagues demonstrated that coquí presence is associated with greater abundances of mongoose (Hill et al. 2019); all of which may contribute to future undesirable effects. Thus, there was reason for the precautionary approach but also reason for skepticism.

While falsifying hypotheses is a natural component of scientific investigation (Popper 2005), we highlight how the temporal conundrum presented by the precautionary principle may elicit public skepticism. When knowledge is missing, people rely on trust for decision-making (Siegrist 2021). However, such reliance requires a foundation of trust. Invasive species risk literature suggests that institutional distrust may arise due to prior failures, and general societal dynamics (e.g. “fake news”) (Norgaard 2007). As context-specific history shapes the public’s (lack of) confidence in invasive species authorities (Crowley et al. 2017a), conspiratorial rhetoric within dissent claims may be indicative of prior conflicts or failures. Low confidence in institutions and scientists have also been observed due to unsafe management practices (Norgaard 2007), perceptions of low efficacy and/or effort in management, and lack of transparency (Wald et al. 2019). Thus, a combination of several factors may have contributed to public distrust in the early stages of coquí management, including 1) safety and pollution concerns of caffeine, the first proposed eradication technique; 2) federal funding challenges stunting the magnitude of early initiatives; 3) the initial limitations in scientific evidence of risks; and/or 4) a historical event or dynamic not observed within this study which nonetheless impacted invasion science-society relationships. Non-dissenters also acknowledged the lack of studies on coquí impacts (Editorial Board 2002b), further suggesting institutional dis/trust plays a role in whether people support expert claims on invasive species sans direct impact evidence. Trust, moreover, is asymmetric in nature such that it is far easier to lose than it is to gain (Slovic 1999).

Disagreement as dissent (high knowledge, low porosity)

Although disagreements arose throughout our sample for varied reasons, including issues related to ethics (i.e., animal rights) and governance (i.e., management infringement on property rights), we highlight message framing as the most prominent obstacle to invasive species support in the case of the coquí. Message framing is critical for its effect on public actionability, or the public’s willingness to accept and act on a given issue (Otieno et al. 2014). Indeed, message framing influences interpretations of invasive species impact and risk. Media message framing shapes information salience by emphasizing certain aspects over others (de Vreese 2005). As discussed in the “Coqui coverage” section, media message framing emphasized the coquí’s call over all other issue frames. Individual-C (2000) illustrates how this overemphasis can contribute to disagreement. Despite exhibiting high knowledge of recent invasive species developments (Fig. 5), they display a strong difference of opinion related to the coquí’s call, and whether the coquí should be prioritized. This situates their comments as disagreement.

FLICC Rhetorical Markers	Low Porosity	They are dismissive in noting their personal experience does not align with the opinion of others	High Knowledge
<u>Anecdote</u> False Equivalence <u>Ad Hominem*</u>		<p>“...Some of us from 4-mile beach in Hilo (<i>Kalanianaole</i>) had the pleasure of visiting the Puna <i>eleutherodactylus coqui</i> (frogs) the other night. We have to disappoint you, [Redacted Name], but the noise level of said frogs in no way compared to what we are subjected to in our neighborhoods on 4-mile. Deafening airplanes flying over the building day and night, and ear/nerve shattering motorcycles continually using Kalanianaole for a drag strip until wee hours of the morning. We have been discussing frogs for what, two years now? <u>Hawaii is mostly all talk when it comes to solving problems!</u> Recently the talk has shifted to the brown tree snakes in Maui endangering the local birds existence. The snakes have been hitchhiking to Hawaii from Guam where there are now an estimated one million snakes. What will we be talking about next year? How to properly insert earplugs? Or shall we sell umbrellas to tourists in Maui so the snakes don't fall on their heads. Maybe we'll have a new income-producing market for Hawaii. 'Huli-Huli Frog legs?' Enough talk already. Let's do something for once about these problems before they get out of hand.” - 9/10/2000, Individual C</p>	Individual is highly knowledgable about invasive species current events

Figure 5. Disagreement. Close reading sample of Individual-C (2000), highlighting FLICC markers as well as the porosity and knowledge characteristics which identify it as disagreement. * This characteristic was determined based on broader context in the back-and-forth engagement between this individual and the redacted.

Individual-C's mention of the brown tree snake's impact on birds, but none of the coquí's ecological impact alludes to how the media's overemphasis on the coquí's call as a social impact overshadows or obscures the species' other potential risks. As people are more likely to support eradication of invasive species with economic and/or ecological impacts (Bremner and Park 2007), this overemphasis on noise likely contributed to heightened dissent around coquí eradication. The media's overemphasis of the coquí problem as a "noise issue", situated coquí impacts in the realm of social negotiation, rather than scientific discussion. Indeed, where the connection between a species and the alleged species' risks is not overtly clear and/or evident, the decision to eradicate and/or control the species will also seem dubious (Wald et al. 2019). Selective attention to social/economic dimensions can lead to environmental impacts that are discounted or ignored altogether, as Essl et al. (2017) contend in the case of the American mink (*Neovison vison*). The American mink is known to impact ground-nesting birds, rodents, amphibians, and the endangered European mink (*Mustela lutreola*) across Europe, yet have also been seen as an important source of revenue for the fur industry in countries like Denmark and Sweden (Bonesi and Palazon 2007). Essl et al. (2017), thus, highlight how normative values and selective attention to different aspects of the issue can create divergent assessments concerning the scale of the issue and what to do about it.

Moreover, the shift in debate from science to social negotiation brings culture, values, and politics to the fore. Individual-C (2000) demonstrates how members of the public may disagree about the severity of immediate social impacts and how they should be addressed, if at all. We agree with the idea that value system disagreements and risk perception are tightly interwoven in invasive species conflicts

(Estévez et al. 2015). Where public support is lacking, or opposition is present, invasive species management initiatives may be stunted (Caceres-Escobar et al. 2019). As a result, disagreement, not grounded in science denialism, may resemble efforts to prevent, stop, or limit invasive species management. Yet, science denialists are often similarly linked to efforts to thwart solutions (Ricciardi and Ryan 2018a; Stuart et al. 2022). Recalling Frank's (2021) emphasis on "normatively inappropriate dissent" in his definition of ISD (see section: "ISD and current limitations to identifying it"), this similarity highlights why invasion science must be intentional with how it conceptualizes science denialism in relation to broader dissent.

Unfamiliarity (low knowledge, high porosity) and Dismissals – a justice concern

Stakeholder engagement in its myriad forms, including through print media, is recognized as a tool for social learning about invasive species (Shackleton and Shackleton 2016). Higher invasive species knowledge tends to be associated with increased education levels and with greater activity in the context of interest/related activities (e.g. boaters have greater knowledge of aquatic invasive species) (Eiswerth et al. 2011). On the other hand, research indicates that low knowledge of invasive species is common among the general public (Colton and Alpert 1998; Randler et al. 2007), which Shackleton and Shackleton (2016) indicate may be attributable to inadequate media coverage (e.g. not targeted enough, flawed messaging). Hence, invasion science scholarship suggests that low stakeholder knowledge of invasive species is indicative of a need to revisit outreach and communication efforts, re-evaluate their effectiveness, and/or broaden their reach (Nanayakkara et al. 2018). Eiswerth et al. (2011) contend this is especially true for more expansive management efforts which require cooperation from a broader constituency. Yet, research on scientist and policy-maker perceptions of stakeholder knowledge illustrate that some scientists perceive stakeholder engagement to be of limited value, due to their association of stakeholder knowledge with misinformation and/or general lack of knowledge (Moon et al. 2015).

The coqui case study illustrates that even stakeholders with limited knowledge of invasive species can carry important contributions for invasive species management and the field. As a long-established cultural symbol of Puerto Rico (Joglar 2005), news of coquí eradication led to some tension between people in Puerto Rico and Hawai‘i, as well as the Puerto Rican diaspora in Hawai‘i and beyond (e.g., Abbott 2001; Balive 2001; Thompson 2001; Wassman 2001; James 2002). Individual-D (2001) broadly captures these various sentiments (Fig. 6)

In this statement, Individual-D (2001) suggests a desire for healthy dialogue indicative of high porosity. They link eradication ("if you happen to catch one) solely to the coqui's sound, demonstrating a low knowledge of the other reasons underlying coqui eradication and invasive species in general. Nonetheless, they flag a need for increased cultural competency. Indeed, this notion of sending frogs "back home" was stated by multiple individuals within the sample, suggesting a literal desire for alternative solutions beyond eradication. This example illustrates how, even unintentionally, invasive species become coupled with discourses about cultural communities and their histories. This call for cultural competency reflects wider critiques of invasion science's rhetoric (Wolschke-Bulmahn 1997; Subramaniam 2001; Larson 2008; Davis et al. 2011; Warren 2011; Reo et al. 2017). For example, Subramaniam (2001)

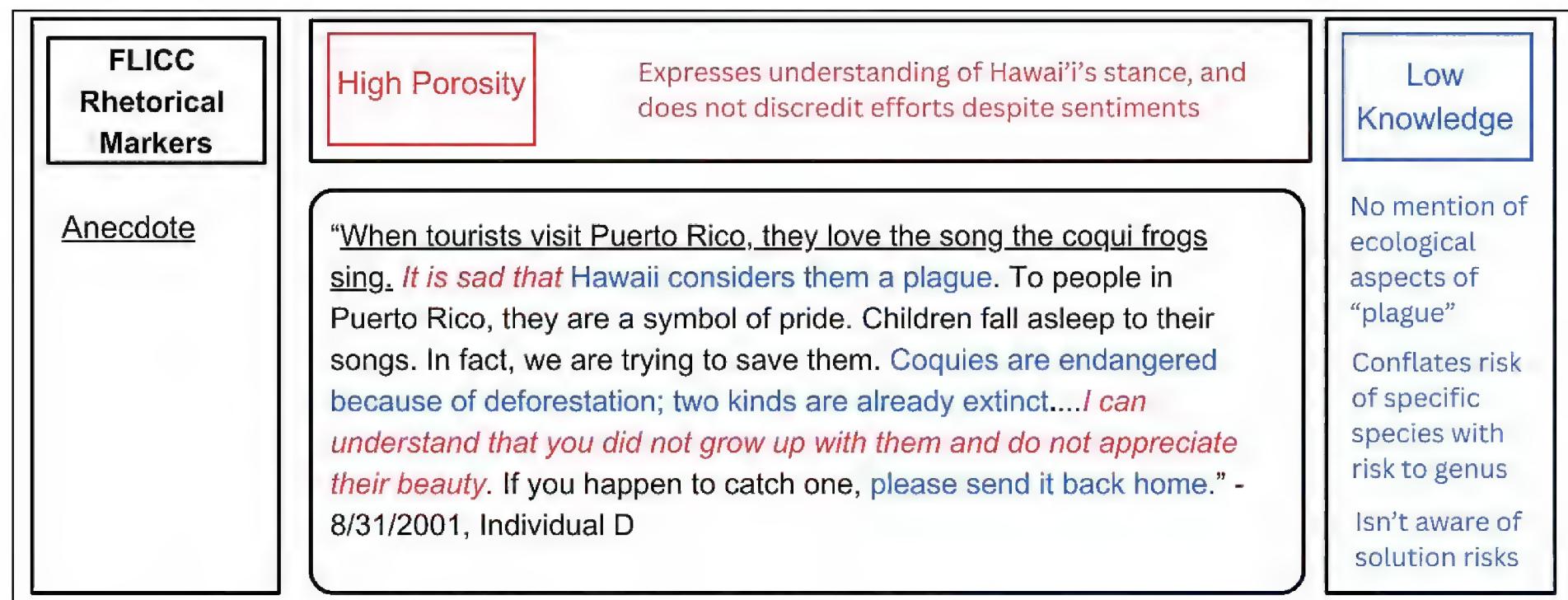


Figure 6. Unfamiliarity. Close read sample of Individual-D (2001), highlighting FLICC markers as well as the porosity and knowledge characteristics which identify it as unfamiliarity.

outline the rhetorical similarities between immigration discourse and invasive species discourse. Reo et al. (2017) push back on discourse in invasion science which fails to depict Indigenous peoples as innovative and proactive invasive species managers. Multiple studies document invasion science's use of militaristic language and metaphors (Larson 2008; Janovsky and Larson 2019). Together, these studies have reiterated calls for the field to reflect on, revisit, and adapt its rhetoric to remove language associated with painful histories and/or harmful ideas. As a field heavily dependent on public participation for successful prevention and rapid response, invasion science cannot afford to alienate people by dismissing their critiques or concerns. Stakeholder engagement can ultimately be counter-productive if stakeholder views are automatically dismissed by scientists and decision-makers (Mackenzie and Larson 2010).

Such discourse concerning cultural competency demands care and suggests that invasion science needs deeper reflection on the language practices within its scholarship and its engagement with diverse publics, particularly as these expressions of cultural disagreement were poorly received in Hawai'i, and often dismissed. As one Honolulu Star Bulletin editorial put it, they were "based on ecological ignorance and should not be taken seriously" (Editorial Board 2002a), a sentiment expressed by some scientists as well:

"This is the point at which some people remember that some other species of frogs around the world are dying off for unknown reasons. Eleutherodactylus is in no such danger, [Scientist A] said. 'These frogs are really tough.' Within this one genus are more species than any other backboned animals on earth, he said. These are 'tramp species' traveling the world with humans, he said. 'These things are similar to rats.'" - (Thompson 2000)

While dissent as unfamiliarity may lead to dismissal, dismissal is not a problem unique to unfamiliarity as skepticism and disagreement may be similarly dismissed. Dismissal of the concerns of invasive species stakeholders has been previously observed within the invasion science literature (Mackenzie and Larson 2010; Crowley et al. 2019; Stratton et al. 2022). The problem of dismissal is one of recognition, a

failure to acknowledge and value another's culture, identity, and/or knowledge, and is an issue which extends beyond ISD to conservation more broadly (Fraser 2008; Guibrunet et al. 2021). Yet, recognitional justice does not mean "anything goes". Rather, it requires consideration and possible modification of power structures and/or systemic cultures such that people are listened to, respected, empowered to speak, and included in decision-making processes (Shackleton et al. 2019). Who defines the problem and how it is defined has implications for what is considered important versus what is deemed irrelevant (Slovic 1999). Indeed, Tassin and Kull (2015) demonstrate how cultural perspectives are an integral, but insufficiently addressed, component of invasive species research and management. Dismissive approaches, such as those utilized by Scientist A, promote an impasse over a productive debate wherein discussants aim to learn from one another, reach resolution, and/or find middle ground (Hoffman 2011). Indeed, studies show that misinformation is best corrected alongside worldview affirmation (Lewandowsky et al. 2012). Without recognition, dismissal of the public's (cultural) concerns may limit learning, alienate potential participants, foreclose collaboration, exacerbate dissent, and, ultimately, entrench power dynamics (Shackleton et al. 2023). Stratton et al. (2022) further suggest that dismissal can bias public engagement and decision-making processes.

Denialism (low knowledge, low porosity)

Geraldi et al. (2019) suggest that media coverage of invasive species is generally short-term, lasting one to two years, due to decreases in newsworthiness and differences between expected ecological impacts and actual outcomes. Our analysis of coquí media elucidates how dissent may elongate anticipated media coverage well beyond the short-term. The difference dissent makes in media coverage produces a paradoxical trade-off for science communication of invasive species. On the one hand, increased media coverage generates greater issue awareness, a substantial obstacle with invasive species when compared to other environmental issues like climate change (Jarić et al. 2020a). Greater invasive species awareness can facilitate early detection, as well as eradication and control efforts, contributing to invasive species management goals (Novoa et al. 2017; Cordeiro et al. 2020). However, greater dissent can also provide fodder for science denialism.

Here, we illustrate how broader dissent arguments can blur into denialism, specifically as science denialists combine broader dissent discourse into their arguments. We find that ISD is present in Hawai'i public media, though stemming from a small number of individuals. Eighteen cases, about 21% of coquí dissent expressions, could be attributed to a single couple (Individual-E and F). However, even limited quantities of science denialism should not be disregarded, as prior research suggests that science denialism need not be massive to shift public perception of scientific consensus (Koehler 2016).

This couple's larger-than-average expression of dissent points to a pattern of iterative engagement. Like broader dissenters, they utilized several rhetorical techniques to combine various dissent threads and morph these expressions into a larger narrative which attempted to discredit scientific authority, undermine institutional trust, and ultimately foster a counter-narrative (Fig. 7). Beyond rhetoric, the couple launched vigorous campaigns against official mitigation efforts, which included coquí protection efforts and pro-coquí publications. Below, we outline a denialist sample text and highlight the way this approach feeds from broader public dissent (Fig. 7).

FLICC Rhetorical Markers	Low Porosity Markers	Equates coqui eradication with being wrong	Disbelief in “” experts	Diminishes scientific facts	Refers to scientists as extremists	Low Knowledge
<u>Fake Experts</u>						Views invasive species agenda as a smear campaign
<u>Conspiracy Theories</u>						Many techniques were tested- caffeine emerged as the most effective
<u>Magnified Minority</u>						Mosquitos have not been found in coqui diets
<u>Anecdotal Evidence</u>						At this point, chytrid fungus was contributing to global declines
<u>False Equivalence</u>						
	Before you jump to the wrong conclusion about the coquis, <i>you should know that the entire anti-coqui agenda has been a carefully planned smear campaign. Fraudulent and exaggerated claims against the frogs have generated hate and intolerance to justify funding for a frog war....When the ‘experts’ claims nothing would kill coqui except caffeine, they did not disclose that the University of Hawaii owns the patent on the caffeine gene, extracted from coffee. This patent was issued in 1999, the same year the frog ‘crisis’ began. If the EPA approved the use of caffeine as a pesticide, the value of this would have increased, along with the stock value of Integrated Coffee Technologies, Inc., sole licensee for the use of the gene, and run by an ex-dean from the university....THE FACT is, there is a silent majority of people in Hawaii who like coquis.</i> Why? Coquis are a natural form of pest control. <i>One man told us that he didn’t like coquis until he saw one eating a cockroach.</i> Coquis also eat termites stinging caterpillars, and the notorious fire ants. People who live with coquis soon notice that mosquito populations are down....Many people also love coquis’ sound at night....However, efforts to control the coqui will be ongoing, since they are virtually impossible to eradicate. And these efforts are dangerous to humans, pets, and plants. Coqui control now involves the experimental use of calcium hydroxide, commonly referred to as hydrated lime, which can cause irreversible eye damage and skin burns, as well as death from inhalation....IT IS ironic that frogs are dying worldwide because of pollution and development, while in Hawaii environmental extremists and exterminators are busy polluting and bulldozing the environment, trying to kill frogs” - 6/7/2005, Individual E					

Figure 7. Invasive species denialism. Close reading sample text of Individual-E (2005), highlighting FLICC markers as well as the porosity and knowledge characteristics which identify it as invasive species denialism.

In describing coquí impact claims as fraudulent and exaggerated, Individual-E (2005) makes several counter claims, including the claim that coquí eat mosquitos. These claims are unsubstantiated. The complete absence of counterevidence, and a failure to point to any scientific gaps (e.g. missing evidence) differentiates this from skepticism. Their limited engagement with coquí science suggests low knowledge. While the coquí as mosquito-catcher claims could initially be attributed to unfamiliarity (Armstrong 2001), scientists have repeatedly debunked this claim based on a study in Puerto Rico and a 2004 study in Hawai‘i (Beard 2007), going as far as informing Individual-E of their misinformation in 2001. The coquí-as-mosquito catcher argument in the sample text, occurring in 2005, illustrates a failure to update their mental model based on new information – a marker of low porosity.

Invasion scientists fear that invasive species benefits such as the coquí-as-mosquito-catcher may be used to offset or underestimate any negative impacts (Lockwood et al. 2023). Our research suggests this is a valid concern as Individual-E, despite active involvement in past coquí discourse, highlighted only what they perceived to be the coquí’s benefits while intentionally omitting any mention of negative impacts. Yet, we see similar benefit claims from other dissent types. Indeed, benefit counter-claims are likely due to the temporal conundrum noted above, and the overall sentiment that invasive species benefits are understated, an idea that is highly polarized within invasion science (Shackleton et al. 2022). In ISD, however, benefit counterclaims may present sticky ideas; that is, they persist, even when repeatedly debunked. As recently as 2019, despite ample reporting and scientific evidence to the contrary, this idea of the coquí-as-mosquito-catcher continues to circulate in Hawai‘i (Dey 2019). Research illustrates that misinformation can be incredibly difficult to combat after-the-fact, as corrections may reinforce beliefs

and/or fail to reduce them (Cook et al. 2015). This suggests it may be important to consider benefits early and widely, as a form of inoculation, before misinformation stickiness develops, rather than in reaction to dissent.

We note that individual-E's arguments are reflected in other examples throughout. For example, their allusion to the global amphibian crisis is evident in the unfamiliarity expressed in Fig. 6 and the atmosphere of "hate" is evident in the response quoted in Fig. 5. This style of additive argumentation is noted in climate change denialism as well (Poortinga et al. 2011), primarily because, as research suggests, science denialism is seldom about the science itself but rather a result of things like personal interest (Kahan et al. 2012; Stratton et al. 2022). Although there is overlap, close engagement and attention to knowledge/porosity can help better differentiate science denialism from broader dissent. Furthermore, as perceptions of consensus are susceptible to the effects of science denialism (e.g. influence of misinformation) (Koehler 2016; Cook et al. 2017), this allusion to the broader dissent discourse presented within the ISD commentary may act as a gateway into denialism from other types of dissent. Due to factors like confirmation bias and motivation bias, invalid or faulty arguments may appear increasingly convincing to members of the public if there is a common idea to bridge them (Correia 2011). Confirmation bias refers to the tendency to gravitate towards information that affirms your beliefs while ignoring that which doesn't, while motivational bias concerns the influence of an individual's desire and emotion on their critical thinking (Correia 2011). Such susceptibilities raise the importance of addressing dissent early and appropriately, particularly if denialism has yet to reach saturation, as Ricciardi and Ryan suggest (2018b).

Conclusion

Dissent can and should be viewed as growing pains, or friction points that will contribute to the field's long-term development (Shackleton et al. 2019). For example, unfamiliarity may highlight the need for greater reflection on the field's language/word choices and/or a gap in educational initiatives. Rather than merely something to eliminate, unfamiliarity can provide an opportunity for scientists and science communicators to reflect on public engagement, and if merited, the field more broadly. Skepticism and disagreement likewise provide a chance to build trust, revisit foundational theories, and open the field to diverse ways of thinking.

While evident in the coquí media of Hawai‘i, ISD constitutes a small but loud problem. For reasons illustrated, utilizing rhetorical techniques and a harm criterion to identify science denialism within invasion science is insufficient for the recognition of ISD. Instead, we propose knowledge base and porosity provide additional benchmarks from which to distinguish science denialism and offer the spectrum of dissent as a starting point to unpacking invasive species dissent. Such an endeavor is fruitful for two principal reasons.

First, appropriately engaging ISD and broader dissent can limit negative repercussions. As denialism mirrors broader dissent, directly addressing or engaging dissent carries the potential to hamper the growth of ISD. Second, carefully distinguishing between ISD and broader dissent allows for invasion science to salvage valuable feedback that can help the field grow and advance. For example, in engaging with dissent throughout this article, we extend the conversation on three inter-related obstacles science communicators must mitigate: 1) the relationship between trust and temporal lags in evidence; 2) the influence of issue framing salience on public perception;

and 3) the danger of dismissal. Although these challenges are not new to invasion science, their relationship to the varied forms of dissent has been less clear – a contribution of this article. As Estévez et al. (2015) suggest, “understanding the root of the conflict should allow the identification of more effective management actions and reconcile tensions before they become entrenched, unmanageable, and destructive”.

Greater stakeholder engagement may help preempt dissent, including but not limited to, co-creation of evidence (i.e. citizen science), invasive species co-prioritization, multi-structured decision-making, etc. (Shackleton et al. 2019). Moon et al. (2015) indicate barriers to invasive species eradication can be mitigated through initiatives like co-management and knowledge co-production, which emphasize power-sharing and equal partnership. Shrestha et al. (2019) illustrate one way to integrate expert and community priorities in their exploration of community invasive species prioritization wherein they prompt participants to rank problematic invasive plants based on impacts and need for management. While this may not be practical in every case (Larson et al. 2017), moving towards a culture of co-creation and implemented stakeholder engagement can foster better science-society relationships that help accommodate urgent problem-solving amidst high uncertainty. Such initiatives not only serve to educate but democratize and legitimate decision-making in the eyes of the public. For example, in a study of landowner perceptions of rapid response programs to address the invasive emerald ash borer, Mackenzie and Larson (2010) suggest that inclusive processes can foster trust which “help to overcome conflicting values and thereby increase satisfaction with potentially unfavorable outcomes”, especially when uncertainties are communicated alongside cost/benefits of available options. This idea, pointing towards outcome improvements upon greater attention to trust and stakeholder engagement processes, is long supported by risk researchers (Slovic 1999).

Ultimately, further research on ISD is merited. Additional work is needed to validate the spectrum of dissent framework at larger scales (e.g., regional, national, global), and within more recent timescales. Similarly, this article focuses on print news media, but more research is needed to determine if any significant differences are evident between news media and social media. Moreover, while numerous studies have offered strategies to address denialism, few have actively tested the efficiency of such approaches (Björnberg et al. 2017), suggesting a productive avenue for interdisciplinary work between scholars in invasion science, environmental communication, and psychology, among others.

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The authors have declared that no competing interests exist.

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Data availability

All of the data that support the findings of this study are available in the main text or Supplementary Information.

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Supplementary material 1

Coding protocol

Authors: Jesann Gonzalez Cruz, McKenzie Johnson

Data type: pdf

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Supplementary material 2

Included media list

Authors: Jesann Gonzalez Cruz, McKenzie Johnson

Data type: xlsx

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